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The Conceptual Design of CubeSat Based System for GNSS Radio Occultation / Reflective Mission

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Introduction

The Global Navigation Satellite System (GNSS) Radio Occultation/Reflective (RO/R) instrument collects global atmospheric data and oceanic wind speed data for weather prediction and climate researches. This paper proposes the conceptual design of the satellite constellation and the satellite to realize the GNSS-RO/R mission based on the cubesat platform, with the goal to achieve cost effectiveness and minimum deployed schedule. The cubesat considered in the study is 12U and within 20 kilogram. The proposed innovative constellation consists of 36 (with 6 backup) satellites on three 600 km altitude sun synchronous planes, 12 satellites even phasing on each plane. It is expected to have 20000 GNSS-RO profile measurements and on-demand GNSS-R profile measurements per day at minimum. The payload instrument will be able to collect RO/R measurements via GPS and GLONASS. The mission lifetime is 3 years. The on-orbit redundancy, instead of redundant satellite components, is adapted to increase system reliability. The satellite design of this study faces very tough challenging to meet the 10-kg mass constraint. The proposed solutions to lower down mass include the creative payload design, the plasma thruster based reaction control subsystem and attitude control subsystem, the use of special non-space grade made-in-Taiwan components, and the creative mission scheduling among satellites to optimize daily global coverage with limited duty cycle of each satellite (the duty cycle can not be 100% because of mass saving on solar array and battery). The study demonstrates the feasibility to achieve the system design. The lessons learned of the system design study have also been introduced. The international cooperation and investment to realize this development is welcome.

Design Philosophy

- **To develop quick and low cost COSMIC System, and establish capability of mass cubesat developer**
- **Efforts to possibly improve some lessons learned with Formosat-7**
  - **Flexible for any possible launch opportunity**

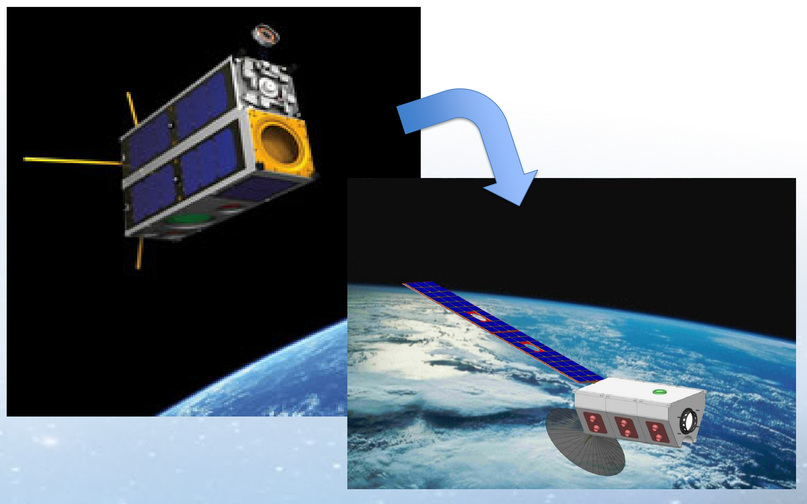
    CubeSat based
  - **Minimum ground station required**
  - **Fast constellation deployment**
  - **Shorter Latency**
  - **Lower system-life cost**

Mission Performance

Item	Spec
Mission	Operations for GNSS RO & R
Operations	Switching between RO and R timely
RO profile	Measurements of 20000 RO profiles per day
Latency	Normally 15 minutes in average 5 minutes for critical operations
Special operations	Hot Spot Tracking operation
Mission lifetime	3 years. The degraded satellite can be replaced from time to time
Ground & data processing	One data downlink ground station, ground high-speed link toward processing

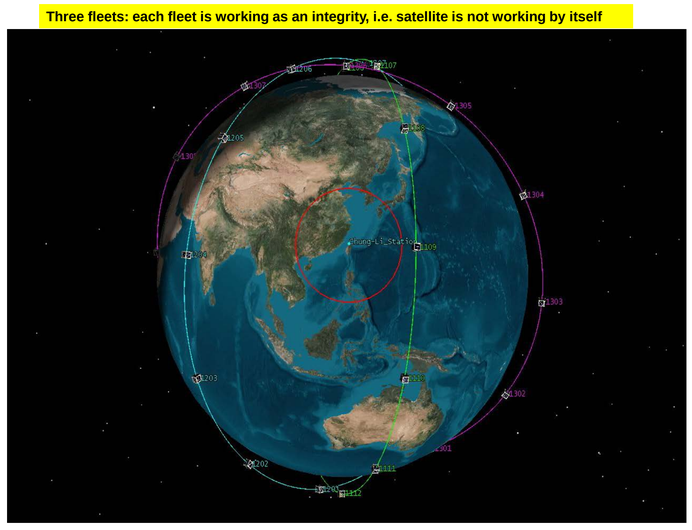
System Architecture

Item	Spec
Orbit	36 cube satellite Three fleets with each of 12 satellites Each fleet on one 600 km altitude sun sync orbit plane Satellite equally phasing
Space segment	GNSS-RO & R payload Inter-satellite link, each fleet inter-integrated, with one designated flag ship which contacts Taiwan
Ground	One data downlink station of polar station Taiwan station as command & contingency data downlink station
Launch	Three launches, each for 12 satellites

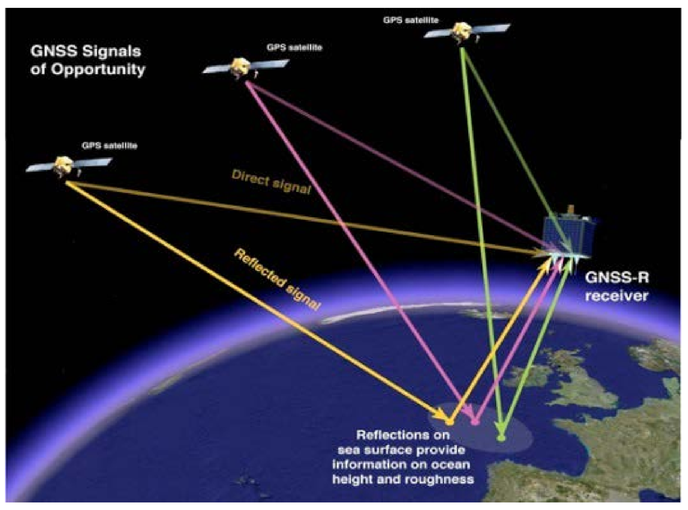


GNSS-RO & R Constellation

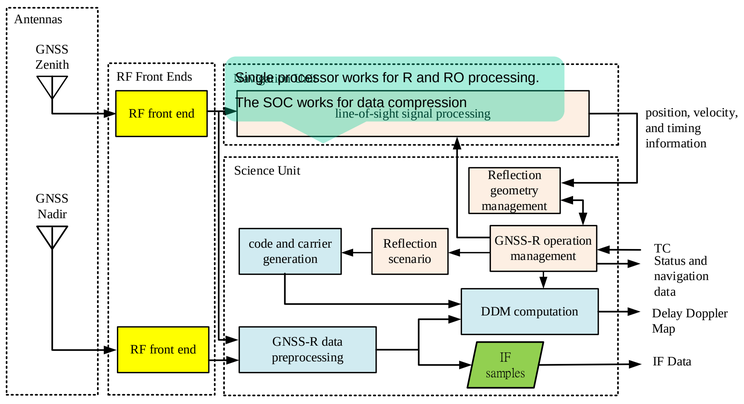
Three fleets: each fleet is working as an integrity, i.e. satellite is not working by itself



How GNSS-R Works

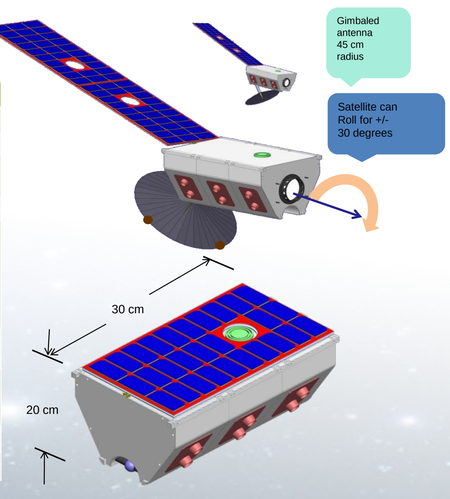


NSPO GNSS-RO & R P/L

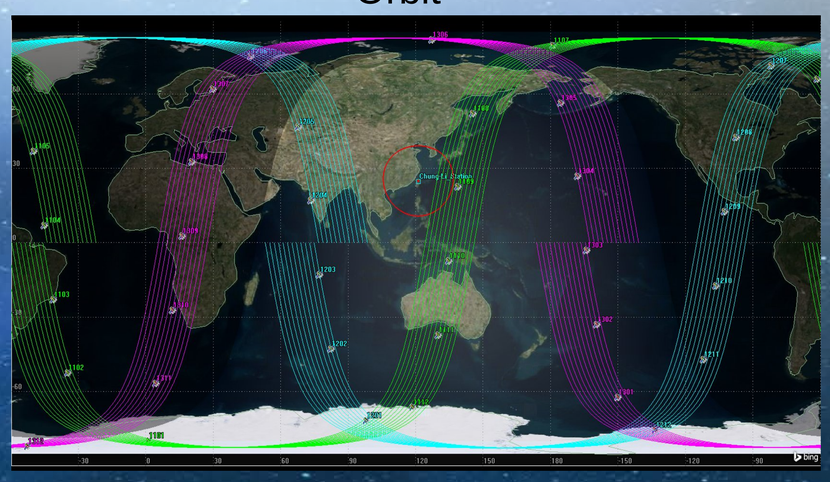


NSPO Satellite

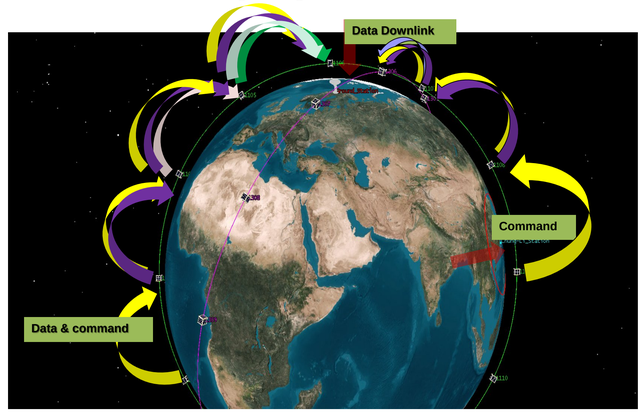
Item	Spec
Size	12U
Mass	20 kg
P/L duty cycle	100%
Agility	Roll for 30 degree
Communication	X band Bi-polarization 8PSK 3 Mbps for each channel one high-gain gimbaled antenna, 45 cm radius
Data storage	Data compression 6 Gbits
Attitude control	Relative* Control accuracy: 0.02 degree Low jitter
Lifetime	3 years
One orbit redundancy	



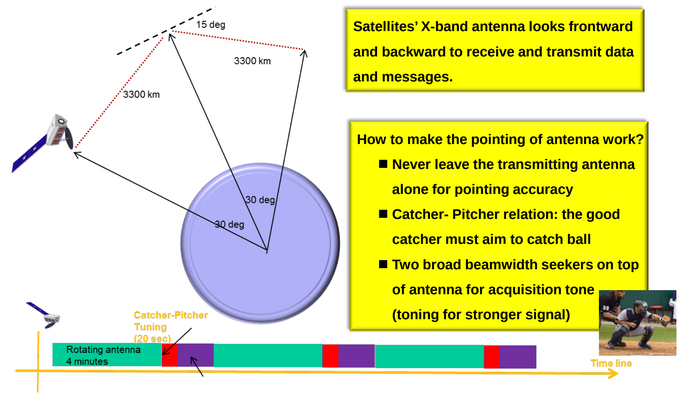
Orbit



Short Latency by Inter-Satellite link

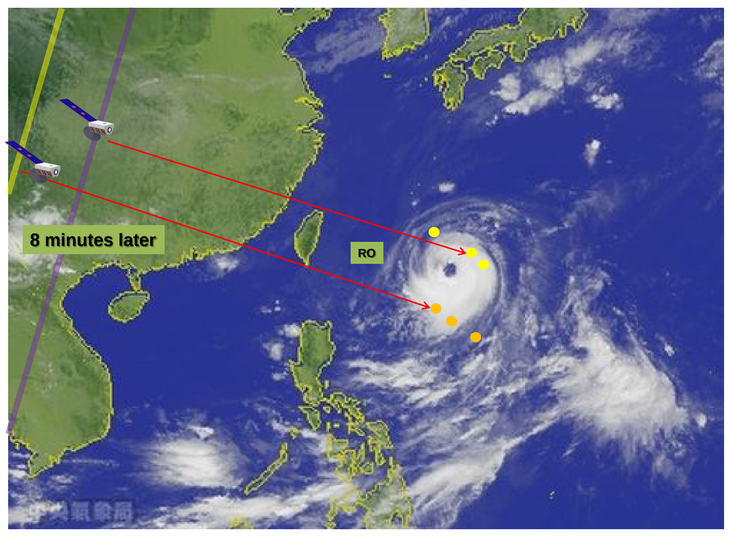


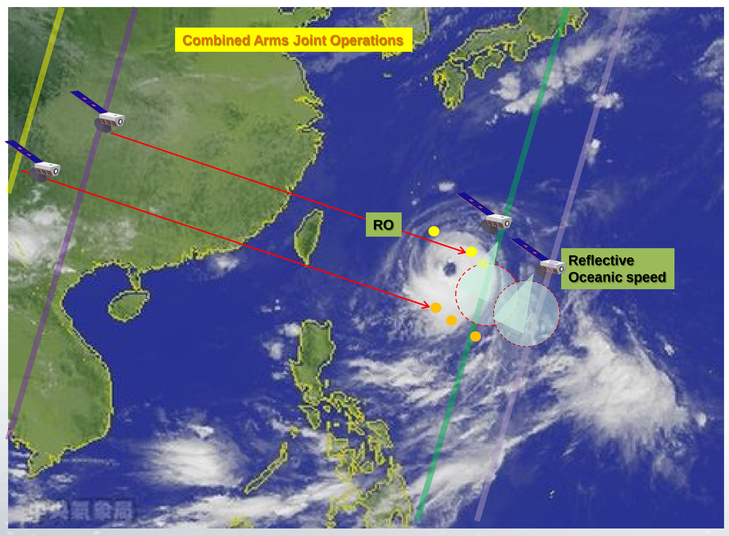
Inter-Satellite link



Hot Spot Tracking Operations

- **For special event, such as typhoon development and approaching, the hot spot can be continuously tracked & monitored .**
  - **Priority operations, latency on demand, near real-time to users (processing center or weather bureau)**
  - **With RO and Reflective (Oceanic speed)**





Short Latency Latency on Demand

- **Short Latency**
  - **Inter-satellite link (data & command) within each fleet**
  - **Periodically satellites of each fleet routing data to the one contacting Svalbard**
  - **Latency of 15 minutes**
- **Latency on Demand**
  - **The flag ship, contacting Taiwan, passing timely commands to all ships of the fleet**
  - **For Priority operations, all ships support the particular satellite to pass data to Svalbard in shortest time**
  - **As short as 5 minutes of latency can be achieved**

Development

- **Schedule (Wishful)**

	2016	2017	2018	2019	2020	2021
System	Conceptual design		EM	TechDemo satellites		FM Launches
Payload development	WSD		EM (H1) PFM (H2)			
Antenna development	WSD		EM (H1) PFM (H2)			
Communication development	WSD		EM (H1) PFM (H2)			

- **Critical (risk) areas**
  - **Communication system design and development**
  - ***Inter-satellite link***
  - ***AOCS design***